Unites States
Coast Guard

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NAVIGATION AND VESSEL INSPECTION CIRCULAR NO. 7-89
Electronic Version for Distribution on the World Wide Web
Subject: Maneuvering Information

1. PURPOSE. The purpose of this Circular is to call attention to IMO Resolution A.601(15), "Provision and Display of Maneuvering Information on Board Ships," adopted 19 November 1987, and MSC/Circ.389, "Interim Guidelines for Estimating Maneuvering Performance in Ship Design," adopted 10 January 1985. These provide guidance to owners and operators concerning maneuvering performance estimation and a standardized format for presentation of ship maneuvering information to operating personnel, including pilots.

2. BACKGROUND.

   a. The Code of Federal Regulations (46 CFR §§35.20, 78.21, 97.19, and 196.19) contains requirements for posting ship maneuvering information on a fact sheet in the pilot house of certain U.S. flag vessels. Title 33 CFR §164.35(g) contains similar requirements for all self-propelled vessels of 1600 or sore gross tons when operating in the navigable waters of the U.S. This fact sheet is used to provide navigators and pilots general information on the ship maneuvering properties and stopping distances as well as vessel speed versus shaft rpm relationship.

   b. The owner, master, or person in charge of a vessel underway is required by 33 CFR §164.11(k) to ensure that a pilot, other than a member of the vessel's crew, be informed of the draft, maneuvering characteristics, and peculiarities of the vessel or any other circumstances that may affect its safe navigation.

   c. The information required by the present regulations is not restricted to a particular format. The 15th Assembly of the International Maritime Organization (IMO) adopted Resolution A.601(15), "Provision and Display of Maneuvering Information on Board Ships." This Resolution provides navigators and pilots more information about the maneuvering conditions and introduces standard formats.

   d. Maneuverability properties are often given only secondary attention during design, at best. This is occasioned by several factors, not the least of which is the lack of maneuvering performance standards and design criteria. MSC/Circ.389 calls attention to this issue.

3. DISCUSSION.

   a. IMO Resolution A.601(15), contained in Enclosure (1), addresses maneuvering information in Pilot Cards, Wheelhouse Posters, and Maneuvering Booklets.

(1) Pilot Card. This card presents in a brief form the current conditions of the ship with regard to its propulsion and steering equipment and loading conditions of the ship. The Pilot Card should be filled out by the ship's master prior to the arrival of the pilot A standardized format for the Pilot Card will benefit all' parties involved and can help to prevent omission of important information when briefing the pilot. A properly completed Pilot Card will satisfy the regulatory requirements of 33 CFR §164.11(k).

(2) Wheelhouse Poster. The Wheelhouse Poster provides more complete information concerning ship hull and engine characteristics than the Pilot Card. In addition, it contains information on stopping distances and trajectories for entering turns at the maximum rudder angle in loaded and ballasted conditions. Use of these standardized wheelhouse posters is helpful in presenting the required information in a form that is readily recognizable by operating personnel and pilots unfamiliar with the vessel. A Wheelhouse Poster will satisfy the present regulatory requirements of 46 CFR.

(3) Maneuvering Booklet. A Maneuvering Booklet may also be developed to provide detailed information about the ship's maneuvering characteristics in different conditions. Appendix 3 of Resolution A.601(15) contains a recommended table of contents and an extensive outline that owners and operators should consider when assembling a Maneuvering Booklet.

b. MSC/Circ.389, contained in enclosure (2), suggests a set of trial maneuvers which have been proposed to quantify a vessel's maneuvering characteristics and recommends that designers estimate these characteristics during the design process.

4. IMPLEMENTATION.

a. Owners of vessels required to post the maneuvering information are urged to use the standardized Wheelhouse Poster contained in IMO Resolution A.601(15).

b. When briefing pilots in accordance with 33 CFR §164.11(k) vessel masters are encouraged to use the Pilot Card recommended in IMO Resolution A.601(15).

c. Officers in Charge, Marine Inspection should stress the advantages of the standardized forms in IMO Resolution A.601(15) to appropriate industry representatives.

d. Designers should study the recommendations in MSC/Circ.389 for possible application during ship design and ship trials.

J. D. SIPES
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Security and Environmental Protection

INTERNATIONAL MARITIME ORGANIZATION

A 15/Res.601
4 January 1988
Original: ENGLISH

ASSEMBLY - 15th session
Agenda item 12

IMO

RESOLUTION A.601(15)
adopted on 19 November 1987

PROVISION AND DISPLAY OF MANEUVERING INFORMATION ON BOARD SHIPS

THE ASSEMBLY,

RECALLING Article 15(j) of the Convention on the International Maritime Organization concerning the functions of the Assembly in relation to regulations and guidelines concerning maritime safety,

RECALLING ALSO that it adopted by resolution A.2O9(VII) the Recommendation on Information to be Included in the Maneuvering Booklets in order to ensure uniformity of such information on board ship,

NOTING the importance attached to further enhancement of the safety of navigation,

RECOGNIZING the need to achieve a uniform format and content of the pilot card and the wheelhouse poster, and to establish a framework for the maneuvering booklet which provides navigators with more detailed information on the maneuvering characteristics of the ship,

HAVING CONSIDERED the recommendation made by the Maritime Safety Committee at its fifty-third session:

1. ADOPTS the Recommendation on the Provision and the Display of Maneuvering Information on Board Ships, as set Out in the Annex to the present resolution, which supersedes the Recommendation adopted by resolution A.209(VII);

2. INVITES all Governments concerned to take steps to give effect to the Recommendation as soon as possible;

3. REQUESTS the Maritime Safety Committee to keep the Recommendation under review for the purpose of improvement based on new developments in techniques and in the light of experience gained in its application.

ANNEX

RECOMMENDATION ON THE PROVISION AND THE DISPLAY OF MANEUVERING INFORMATION ON BOARD SHIPS

I INTRODUCTION

1.1 In pursuance of the Recommendation on Data Concerning Maneuvering Capabilities and Stopping Distances of Ships, adopted by resolution A.160(ES.IV), and paragraph 10 of regulation 11/1 of the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, 1978, Administrations are recommended to require that the maneuvering information given herewith is on board and available to navigators.

1.2 The maneuvering information should be presented as follows.

.1 Pilot card

.2 Wheelhouse poster

.3 Maneuvering booklet.

2 APPLICATION

2.1 The Administration should recommend that maneuvering information, in the form of the models contained in the appendices, should be provided as follows:

.1 for all new ships to which the requirements of the 1974 SOLAS Convention, as amended, apply, the pilot card should be provided;

.2 for all new ships of 100 meters in length and over, and all new chemical tankers and gas carriers regardless of size, the pilot card, wheelhouse poster and maneuvering booklet should be provided.

2.2 The Administration should encourage the provision of maneuvering information on existing ships, and ships that may pose a hazard due to unusual dimensions or characteristics.

2.3 The maneuvering information should be amended after modification or conversion of the ship which may alter its maneuvering characteristics or extreme dimensions.

3. MANEUVERING INFORMATION

3.1 Pilot card (appendix 1)

The pilot card, to be filled in by the master, is intended to provide information to the pilot on boarding the ship. This information should describe the current condition of the ship, with regard to its loading, propulsion and maneuvering equipment, and other relevant equipment. The contents of the pilot card are available for use without the necessity of conducting special maneuvering trials.

3.2 Wheelhouse poster (appendix 2)

The wheelhouse poster should be permanently displayed in the wheelhouse. It should contain general particulars and detailed information describing the maneuvering characteristics of the ship, and be of such a size to ensure ease of use. The maneuvering performance of the ship may differ from that shown on the poster due to environmental, hull and loading conditions.

3.3 Maneuvering booklet (appendix 3)

The maneuvering booklet should be available on board and should contain comprehensive details of the ship's maneuvering characteristics and other relevant data. The maneuvering booklet should include the information shown on the wheelhouse poster together with other available maneuvering information. Most of the maneuvering information in the booklet can be estimated but some should be obtained from trials. The information in the booklet may be supplemented in the course of the ship's life.

APPENDIX 1

PILOT CARD

Ship's name ______________________ Date ____________

Call sign ____________ Deadweight ____________ tonnes Year built ________

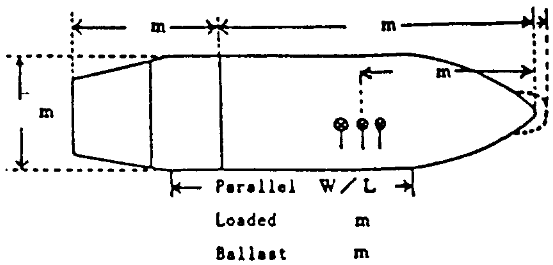
Draught Aft _____ m/ __ ft __ in. Forward _____ m/ __ ft __ in. Displacement _______ tonnes

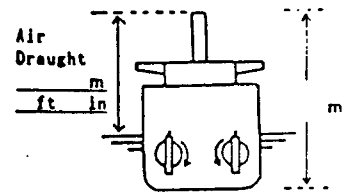
SHIP'S PARTICULARS

Length overall _________ m. Anchor chain : Port _____ shackles, Starboard _____ shackles,

Breadth _________ m " Stern _____ shackles

Bulbous bow Yes/No (1 Shackle = _______ m/ _______ fathoms)





Type of engine ____________________ Maximum power __________ kw (__________ HP)

Manoeuvring Engine order	Rpm/pitch	Speed (knots) Loaded	Speed (knots) Ballast
Full ahead			
Half ahead			
Slow ahead			
Dead slow ahead			
Dead slow astern		Time limit astern ________ min	
Slow astern		Full ahead to full astern ________ sec	
Half astern		Max. no. of consec. starts ________	
Full astern		Minimum RPM ________ , ________ knots	
		Astern power ________ % ahead	

STEERING PARTICULARS

Type of rudder ____________, Maximum angle ______°, Hard-over to hard-over _____ sec

Rudder angle for neutral effect ______°

Thruster : Bow ________ kW(________ HP), Stern ________ kW(________ HP)

CHECKED IF ABOARD AND READY

Anchors [ ]

Whistle [ ]

Radar [ ] 3cm [ ] 10cm

ARPA [ ]

Speed log [ ] Doppler:Yes/No

Water speed [ ]

Ground speed [ ]

Dual-Axis [ ]

Engine telegraphs [ ]

Steering gear [ ]

Number of power units operating [ ]

Indicators : Rudder [ ]

Rpm/Pitch [ ]

Rate of Turn [ ]

Compass System [ ]

Constant Gyro Error ± _____°

VHF [ ]

Elec. Pos. Fix. System [ ]

Type ________________

OTHER INFORMATION :

APPENDIX 2

WHEELHOUSE POSTER

Ship's name______________________. Call Sign______________. Gross tonnage____________________. Net tonnage________________

Max. displacement_______________tonnes, and Deadweight_______________tonnes, and Block coefficient __________ at summer full load drought

Draught at which the manoeuvring data were obtained

Loaded	Ballast
Trial/Estimated	Trial/Estimated
_____m forward	_____m forward
_____m aft	_____m aft

STEERING PARTICULARS	
Type of rudder (s)	______________________
Maximum rudder angle	__________°
Time hard over to hard over with one power unit	_________sec
with two power units	_________sec
Minimum speed to maintain course propeller stopped	______knots
Rudder angle for neutral effect	__________°

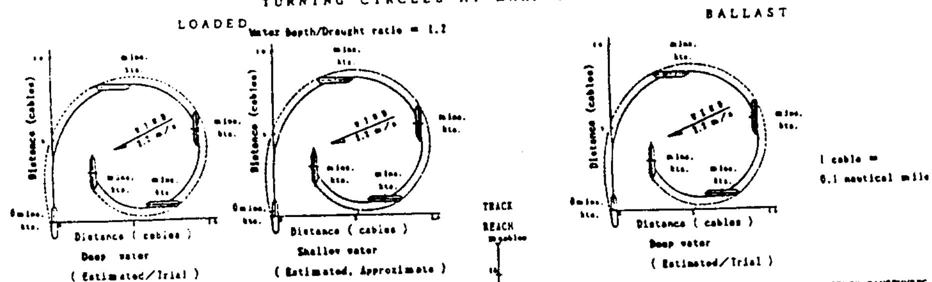
ANCHOR CHAIN	No. of shackles	Max. Rate of heaving (min/shackle)
Port		
Starboard		
Stern		
(1 shackle = _____m / _____fathoms)		

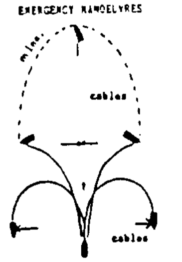
PROPULSION PARTICULARS			
Type of engine_________, _____kW(_____HP), Type of propeller_____			
Engine order	Rpm/pitch setting	Speed (knots) Loaded	Speed (knots) Ballast
Full sea speed			
Full ahead			
Half ahead			
Slow ahead			
Dead slow ahead			
Dead slow astern		Critical revolutions _________rpm	
		Minimum RPM________ _________knots	
Slow astern		Time limit astern _________min	
		Time limit at min. revs._______min	
Half astern		Emergency full ahead to full astern _________sec	
		Stop to full astern _________sec	
Full astern		Astern power _________% ahead	
		Max. no. of consecutive starts_______	

THRUSTER EFFECT at trial conditions					
Thruster	kW(HP)	Time delay for full thrust	Turning rate at zero speed	Time delay to reverse full thrust	Not effective above speed
Bow		sec	°/min	min sec	knots
Stern		sec	°/min	min sec	knots
Combined		sec	°/min	min sec	knots

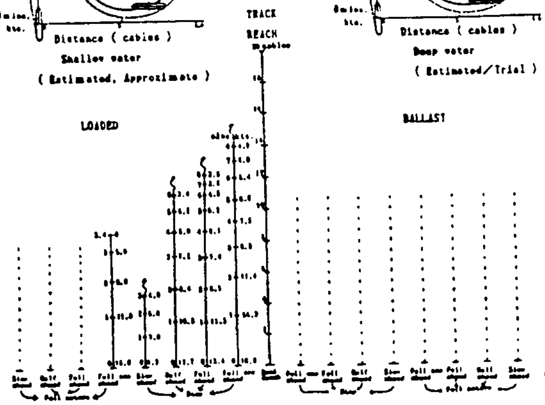
DRAUGHT INCREASE (LOADED)				
Estimated Squat Effect			Heel Effect	
Under keel clearance	Ship's speed (knots)	Max. bow squat estimated (m)	Heel angle (degree)	Draft increase (m)
m			2	
			4	
			8	
m			12	
			16	

TURNING CIRCLES AT MAX. RUDDER ANGLE

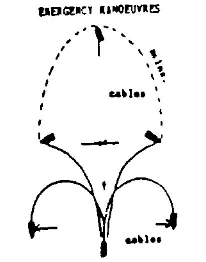




Comparison of Turning (max. rudder) and Full Astern Stopping Ability (rudder amidships)



STOPPING CHARACTERISTICS



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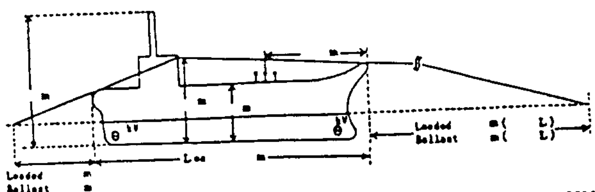

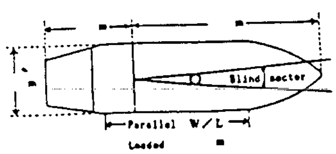

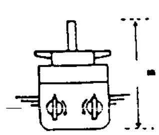

MAN OVERBOARD RESCUE MANOEUVRE
SEQUENCE OF ACTIONS TO BE TAKEN: • TO CAST A LIFE BUOY • TO GIVE THE HELM ORDER • TO SOUND THE ALARM • TO KEEP THE LOOK-OUT
Insert a recommended turn

PERFORMANCE MAY DIFFER FROM THIS RECORD DUE TO ENVIRONMENTAL, HULL AND LOADING CONDITIONS

Prepared by __________
Date __________

APPENDIX 3

RECOMMENDED INFORMATION TO BE INCLUDED IN THE MANEUVERING BOOKLET

CONTENTS

1 General description

1.1 Ship's particulars

1.1.1 General
Ship's name, distinctive number or letters, year of build

1.1.2 Gross tonnage and other information
Gross tonnage, deadweight and displacement (at summer draught)

1.1.3 Principal dimensions and coefficients
Length overall, length between perpendiculars, breadth (moulded), depth (moulded), summer draught, normal ballast draught, hull coefficients at summer load and normal ballast condition
Extreme height of the ship's structure above the keel

1.1.4 Main engine
Type, number of units and power output

1.1.5 Propeller
Type, number of units, diameter, pitch, direction of rotation, propeller immersion

1.1.6 Rudder
Type, number of units, total rudder area, rudder area ratio (full load and normal ballast)

1.1.7 Bow and stern thrusters
Type, number of units, capacities and location

1.1.8 Bow and stern profiles

1.1.9 Forward and after blind zones with dimensions specified (full load and normal ballast)

1.1.10 Other hull particulars
Projected areas of longitudinal and lateral above-water profiles (full load and normal ballast)
Length of parallel middle body for berthing (full load and normal ballast)

1.2 Characteristics of main engine

1.2.1 Maneuvering speed tables (trial or estimated, at the full load and ballast conditions)
Engine revolutions, ship speed and thrust (at ahead) corresponding to engine orders

1.2.2 Critical revolutions

1.2.3 Time for effecting changes in engine telegraph settings as in 3.1.2 for both routine and emergency conditions

1.2.4 Time limit astern

1.2.5 Minimum operating revolutions (for diesel engines) and corresponding ship speed

1.2.6 Maximum number of consecutive starts (for diesel engines)

2 Maneuvering characteristics in deep water

2.1 Course change performance

2.1.1 Initial turning test results (trial or estimated, at the full load and ballast conditions), test conditions, diagrams of heading angle versus time and Ships track

2.1.2 Course change test results (trial or estimated, at full load and ballast conditions)

Curves of course change distance and point of initiation of counter rudder for the necessary course change angle (for both full load and ballast conditions)

2.2 Turning circles in deep water (trial or estimated, at the full load and ballast conditions)

2.2.1 Turning circle test results
Test conditions, test results (advance and transfer) and turning track at full sea speed ahead

2.2.1.1 Turning circles in both full load and ballast conditions (stern track should be shown)

2.2.1.2 The data presented should refer to the case of starboard turn only (unless there is significant difference for port turn)

2.2.1.3 The initial speed of the ship should be full sea speed ahead

2.2.1.4 Times and speeds at 90^0, $l80^0$, 270^0 and 360^0 turning should be specifically shown together with an outline of the ship

2.2.1.5 The rudder angle used in the test should be the maximum rudder angle

2.3 Accelerating turn (trial or estimated)
Data are to be presented for bath full load and ballast conditions in the same manner as 2.2 for turning circles. The ship accelerates from rest with the engine full maneuvering speed ahead and the maximum rudder angle

2.4 Yaw checking tests (trial or estimated)

2.4.1 Results of the zig-zag and pull-out maneuver tests at the full load or ballast condition shown as diagrams of the heading changes and rudder angle

2.5 Man-overboard and parallel course maneuvers

2.5.1 Man-overboard maneuver (trial)
Diagrams for cases of both starboard and port turns should be shown for both full load and ballast conditions

2.5.2 Parallel course maneuver (estimated)
Diagrams showing lateral shift to a parallel course using maximum rudder angle

2.6 Lateral thruster capabilities (trial or estimated)

2.6.1 Diagrams of turning performance at zero forward speed in the full load or ballast condition should be shown, for bow and stern thrusters acting separately and in combination

2.6.2 Diagrams showing the effect of forward speed on turning performance should be included

2.6.3 Information on the effect of wind on turning performance should be given

3 Stopping and speed control characteristics in deep water

3.1 Stopping ability

3.1.1 Stopping test results (trial)
Test conditions, ship's tracks, rpm, speed, track reach, head reach and side reach
Two or more tests should be carried out including a test of full astern from full sea speed ahead and a test of full astern from full ahead speed.

3.1.2 Stopping ability (estimated)
Information and diagrams should be given of the track reach, head reach, side reach, time required and track reach deceleration factor (distance/one knot reduction) of a ship in both full load and ballast conditions covering the following modes of stopping maneuvers:

full astern from full sea speed ahead
full astern from full ahead speed
full astern from half ahead speed
full astern from slow ahead speed
stop engine from full sea speed ahead
stop engine from full ahead speed
stop engine from half ahead speed
stop engine from slow ahead speed

3.2 Deceleration performance (estimated)

3.2.1 Deceleration ability (estimated)
Information and diagrams should be given concerning the track reach, time required and deceleration factor of the ship in both full load and ballast conditions for the following engine orders

full sea speed to "stand by engines"
full ahead to half ahead

half ahead to slow ahead
slow ahead to dead slow ahead

3.3 Acceleration performance (estimated)

3.3.1 Information and diagrams should be given for track reach and time for the ship to achieve full sea speed ahead, from zero speed

4 Maneuvering characteristics in shallow water

4.1 Turning circle in shallow water (estimated)

4.1.1 Turning circle in the full load condition (stern track to be shown)

4.1.2 The initial speed of the ship should be half ahead

4.1.3 Times and speeds at 90^0, 180^0, 270^0 and 360^0 turning should be specifically shown, together with an outline of the ship

4.1.4 The rudder angle should be the maximum and the water depth to draught ratio should be 1.2

4.2 Squat (estimated)

4.2.1 Curves should be drawn for shallow water and infinite width of channel, indicating the maximum squat versus ship speed for various water depth/draught ratios

4.2.2 Curves should be drawn for shallow and confined water, indicating the maximum squat versus speed for different blockage factors

5 Maneuvering characteristics in wind

5.1 Wind forces and moments (estimated)

5.1.1 Information should be given on the wind forces and moments acting on the ship for different relative wind speeds and directions in both full load and ballast conditions, to assist in berthing

5.2 Course-keeping limitation (estimated)

5.2.1 Information should be given for both full load and ballast conditions, showing the effect of wind on the ability of the ship to maintain course

5.3 Drifting under wind influence (estimated)

5.3.1 Information should be given on the drifting behavior under wind influence with no engine power available

6 Maneuvering characteristics at low speed (trial or estimated)

6.1 Information on the minimum operating revolutions of the main engine and corresponding ship's speed should be given

6.2 Information on the minimum speed at which the ship can maintain course while still making headway after stopping engines

7 Additional information

7.1 Any other relevant additional information should be added to the contents of the booklet, particularly information concerned with the operation of the bridge maneuvering controls.

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MSC/Circ.389
10 Jan 1985

Ref. T4/3.03

IMO

INTERIM GUIDELINES FOR ESTIMATING MANEUVERING
PERFORMANCE IN SHIP DESIGN

The Maritime Safety Committee, at its fiftieth session, approved Interim Guidelines for Estimating Maneuvering Performance in Ship Design, attached at Annex, which have been developed by the Sub-Committee on Ship Design and Equipment.

It is intended that the interim guidelines should form the basis for assessing data to be used, and possibly further developed, on maneuverability and performance standards for all types of ships.

Member Governments are invited to request shipyards to apply the interim guidelines as early as possible on a trial basis so that they may be assessed in the light of the practical experience gained.

Member Governments are also invited to collate the maneuverability data on ship performance obtained, and to submit it to the Sub-Committee on Ship Design and Equipment where it will be evaluated and applied in reviewing the interim guidelines.

ANNEX

DRAFT INTERIM GUIDELINES FOR ESTIMATING MANEUVERING PERFORMANCE IN SHIP DESIGN

1 INTRODUCTION

All ships should have maneuvering qualities which permit them to keep course, to turn, to check turns, to operate at acceptably slow speeds and to stop, all in a satisfactory manner. Since most maneuvering qualities are inherent in the design of the hull and machinery they should be consciously estimated during the design process. These interim guidelines define specific maneuvering characteristics which quantify maneuverability and recommend estimation of these characteristics during design both for the fully loaded and test condition in deep water. They also outline full scale tests to confirm the maneuvering performance in the test condition. Maneuvering performance of all new ships greater than 100 meters in length should be estimated using these guidelines. The Administration should decide to what extent the interim guidelines should apply to smaller ships. Although the guidelines are intended to apply to ships with rudders of conventional design, ships with unconventional steering arrangements should be included by the use of an equivalent control setting.

2 DESCRIPTION OF MANEUVERING CHARACTERISTICS

Maneuvering capabilities of ships can be determined if the characteristics described below and in the Appendix are known.

2.1 Turning circle characteristics

Turning circle characteristics can be determined from the steady turning circle tests using a rudder angle of 35^0, or a maximum design rudder angle permissible at the test speed. The essential characteristics are defined in figure 1 of the Appendix.

2.2 Yaw checking ability

Yaw checking ability can be determined by the first overshoot angle and time to check the yaw in a zig-zag maneuver. These parameters are defined in figure 2 of the Appendix. The rate of rudder movement has effects on this ability.

2.3 Initial turning ability

Initial turning ability can be determined from the change of a ships heading angle per unit rudder angle and the distance traveled after a rudder command is executed, as described in the Appendix.

2.4 Course keeping ability

Course keeping ability is the capacity of the steered ship to correct for increasing heading errors before they become unacceptably large. While there is no simple index of this quality, it is closely related to the dynamic stability of the ship, as described in the Appendix and illustrated in figures 3, 4 and 5.

Consideration should be given to the neutral rudder angle necessary for proceeding on a straight course.

2.5 Slow steaming ability

The ability to proceed at steady slow speed can be determined from the ship's speed associated with the lowest possible engine revolutions per minute in calm weather conditions. This is only intended to address engine conditions and not steering control.

2.6 Stopping ability

Stopping ability can be determined from the distance a ship travels along its track once a crash astern order is given. This distance is defined as track reach in figure 6 of the Appendix.

3 ESTIMATION AND COMPARISON OF MANEUVERING AND COURSE KEEPING QUALITIES

The maneuvering qualities of a particular ship may be estimated by calculation, model testing or the use of a data base that contains ships of similar configuration, size and speed. These estimates can then be compared with the results of the turning circle, zig-zag and stopping tests.

The course keeping ability may be inferred by taking into account the size and speed of the ship together with the overshoot angle from the zig-zag test, the spiral loop width, or the residual rate of turn from the pull-out test.

4 APPLICATION

4.1 The Administration should recommend shipbuilders to use these guide-lines during a ship's design process and also to indicate whether they have done so. Such indication should include information about the method used.

4.2 Tests should be conducted to compare the ship's actual maneuvering performance with the designer's estimation. Where circumstances permit, these tests should be carried out in deep water with favorable environmental conditions. The Appendix describes the types of tests that may be conducted, at least for the first ship of a particular design.

4.3 Upon completion of the ship's tests, the shipbuilder should examine the data with a view to establishing the validity of the prediction methods used for describing the ship's maneuvering characteristics and submit the results to the Administration.

APPENDIX

DESCRIPTION OF STANDARD MANEUVERS

Certain definitive maneuvers have become established as "standard maneuvers" to define the course keeping characteristics and maneuvering capabilities of a ship. The description given here draws upon a number of codes available from different organizations, mainly the 1975 International Towing Tank Conference (ITTC) Maneuvering Trial Code.

The definitive maneuvers relate to such characteristics which are inherent in the design of the ship.

The test speed as used in these guidelines is defined as the speed at which a ship may be expected to navigate in areas where manicures are normally required, and are not restricted by insufficient water depth or channel boundaries.

In the case of slow, full form ships this speed may be close to design sea speed. On the other hand for fast, fine form ships it may be a much lower proportion of design speed. The following formula is suggested as a guide to selecting test speed:

$$V_T = C_B \, x V_D$$

where V_T = test speed
V_D = design speed
C_B= block coefficient at the design draught.

This formula provides test speed values for bulk carriers and dry cargo/container ship types which are often used in general practice. Unless otherwise indicated tests should be commenced at the test speed.

A ship is said to be “dynamically stable on a straight course” if, following a finite disturbance, it soon resumes its straight motion in a slightly different direction without any correcting rudder being applied. The magnitude of the change of direction is characteristic for the ship and for the magnitude of the disturbance.

If the ship is "dynamically unstable on a straight course" a finite disturbance, however small, will cause the ship if unsteered to enter a turn to one side or the other, ending up in a turning circle of a certain curvature, in which its motion is now stable with zero or "neutral" rudder. This curvature also defines the steady turning rate, which is equal to the height of the instability loop displayed in the steady-state turning-rate versus rudder angle diagram derived from the spiral test (see 4.2 and 4.3).

TEST PROCEDURES

1 <u>Turning circle tests</u>

To be performed to both starboard and port with 35^0 rudder angle or the maximum design rudder angle permissible at the test speed.

The essential information to be obtained from this maneuver consists of tactical diameter, advance and transfer (see figure 1). Also of interest are the final ship speed and yaw rate in the "steady state" of the turning circle. A turning circle of at least 5400 should be completed to determine the main parameters of the maneuver and allow correction for any drift caused by a steady current or wind.

At the completion of each of the turning circle tests a pull-out maneuver may be performed to provide information on the ship's dynamic stability.

The tactical diameter, advance and transfer may also be presented in non-dimensional form by dividing their values by the ship's length between perpendiculars. The ratio of length over turning radius is a non-dimensional measure of the yaw rate.

2 Zig-zag tests

The standard type zig-zag tests are the $\delta = 10^0$ (rudder) / $\Psi = 10^0$ (change of heading at rudder execute) and $20^0/20^0$ tests. "Modified" zig-zag tests, such as the $20^0/10^0$ test, are frequently performed in long towing basins, in narrow waters and for reasons of special analysis.

At least one standard type zig-zag test should be performed at the test speed. The $10^0/10^0$ test is preferred, as it provides better discrimination between ship characteristics but the $20^0/20^0$ test should be included to provide a comparison with data available from earlier tests. For similar reasons of comparison the $20^0/10^0$ test may be taken into consideration.

The zig-zag test as shown in figure 2 is obtained by reversing the rudder alternately by δ degrees to either side at a deviation Ψ from the initial course. After a steady approach with zero yaw rate the rudder is put over to starboard (first execute) and kept as steady as possible. When the heading is Ψ degrees off the initial course, the rudder is reversed to the same position to port (second execute). After counter rudder has been applied, the ship continues turning in the original direction with decreasing turning speed until the movement is decayed. Then, in response to the rudder the ship should turn to port. When the heading is Ψ degrees off the course to port, the rudder is reversed again to starboard (third execute). This process may be continued until a total of 5 rudder executes have been completed, if required for other analysis. A pull-out test may also be performed upon completion of the zig-zag test.

The essential information to be obtained from the zig-zag tests are the initial turning time t_a (see section 3) to second execute, the time to check yaw, t_s, and the angle of overshoot α (see figure 2). In addition an analysis of the zig-zag test furnishes values of the steering indices K (gain constant) and T (time constant) associated with linearized steering theory.

3 Initial turning tests

The initial turning tests provide information on the transient heading condition between steady state approach and change of heading after application of the rudder. These tests should be performed with rudder angles of 10^0 and 20^0. The time history of heading and yaw rate should be plotted. These tests may be combined with zig-zag tests (see section 2) and turning circle tests (see section 1).

4 Course keeping information tests

Information on course keeping characteristics can be obtained from the zig-zag tests, the pull-out tests and the direct and reversed spiral tests. For the zig-zag tests, see section 2 above.

4.1 The pull-out tests

The pull-out tests give a simple indication of a ship's dynamic stability on a straight course (see above). The ship is first made to turn with a certain rate of turn in either direction, upon which the rudder is returned to midship. If the ship is stable, the rate of turn will decay to zero for turns to both port and starboard. If the ship is unstable, then the rate of turn will reduce to some residual rate of turn. The pull-out tests should be performed to both port and starboard to show a possible asymmetry (see figure 3). Normally, pull-out tests are performed in connection with the turning circle tests (see section 1), zig-zag tests (see section 2) or initial turning tests (see section 3), but they may be carried out separately.

4.2 The direct spiral test

The direct spiral test is an orderly sequence of turning circle tests to obtain a steady-turning-rate versus rudder angle relation (see figure 4).

In case there are reasons to expect the ship to be dynamically unstable, or only marginally stable, a direct spiral test will give additional information. This is a time consuming test to perform especially for large and slow ships. A significant amount of time is needed for the ship to obtain a steady rate of change of heading after each rudder angle change. Also the test is very sensitive to weather conditions.

With the ship on an initial straight course, the rudder is put to about 20^0 starboard and held until the rate of change of heading is constant. The rudder angle is then decreased by 5^0 and again held until steady conditions of turning have been obtained. 'This procedure is repeated until the rudder has covered the range from 20^0 on one side to 20^0 on the other side and back again. Over a range of rudder angles of 5^0 to 10^0 on either side of zero or neutral rudder angle these intervals should be reduced to 1^0.

In cases where the ship is dynamically unstable it will appear that it is still turning steadily in the original direction although the rudder is now slightly deflected to the opposite side. At a certain stage the yaw rate will abruptly change to the other side and the yaw rate versus rudder angle relation will now be defined by a separate curve. Upon completion of the test the results will display the "hysteresis loop" presented in figure 4. Similar tests with a stable ship will result in a curve as shown in figure 5.

4.3 The reverse spiral test

The reverse spiral test may provide a more rapid procedure than the direct spiral test to define the instability loop as well as the unstable branch of the yaw rate versus rudder angle relationship indicated by the dotted curve as shown in figure 4. In the reverse spiral test the ship is steered at a constant rate of turn and the mean rudder angle required to produce this yaw rate is measured.

The necessary equipment is a properly calibrated rate of turn indicator and an accurate rudder angle indicator. Accuracy can be improved if continuous recording of rate of turn and rudder angle are available for the analysis. In certain cases the test may be performed with the automatic steering devices available on board.

If manual steering is used, the instantaneous rate of turn should be visually displayed to the helmsman, either on a recorder or on a rate of turn indicator.

Using the reverse spiral test technique, points on the curve of yaw rate versus rudder angle may be taken in any order.

The procedure for obtaining a point of the curve should be as follows:

The ship is made to approach the desired rate of turn, by applying a moderate rudder angle. As soon as the desired rate of turn is obtained, the rudder is actuated such as to maintain this rate of turn as precisely as possible, using progressively decreasing rudder motions until steady values of speed and rate of turn have been obtained. Steady rate of turn should usually be obtained fairly rapidly since rate-steering is easier to perform than normal compass steering.

This procedure should be repeated for a range of yaw rates, etc. until a complete yaw rate versus rudder angle relationship is established, e.g. between 150 port to 150 starboard rudders.

The results of the spiral tests should be presented in accordance with the diagrams as shown in figures 4 or 5. The diagrams may be complemented by the appropriate figures derived from pull-out and steady state turning circle tests. Again, the yaw rates may be given in non-dimensional form as indicated for the turning circle tests in section 1.

5 Stopping tests

Stopping tests should be performed from the test speed with maximum full astern power.

As indicated in figure 6, the ship's track and heading after the astern order should be plotted versus the time. Head reach and lateral deviation may be presented in absolute values and also in non-dimensionalized form (in terms of the number of ship lengths). Moreover$_1$ the time l~ between issuing the astern order and the moment when the propeller stops and reverses (or when the pitch of controllable pitch propellers is reversed) should be measured.

TEST RECORDING

1 Turning circles, initial turning test, pull-out, zig-zag test, crash stop and recorded versus time

- Revolutions per minute (RPM) of the propeller and the pitch setting
- Rudder angle
- Successive positions of the ship (not compulsory for pull-out)
- Ship speed
- Heading and rate of change of heading, i.e. yaw rate

2 Direct and reverse spiral tests

- Rudder angle
- Ship speed

- Rate of turn

3 Additional information included in the test protocol

Besides information on the ship conditions, viz:

- Draught and trim
- Displacement
- Test speed and corresponding number of revolutions (RPM) the following environmental conditions should be noted:
- Depth of water
- Sea state and swell
- Wind direction and speed
- Current direction and speed
- Initial course, relative to wind direction

GENERAL REMARKS

All maneuvering tests should preferably be performed at a wind force not exceeding Beaufort No.4 (depending on ship speed and characteristics) in deep water and with other environmental conditions acceptable for the test being performed.

For all the tests, measurements should be commenced during the approach period, two or three minutes before the first execute.

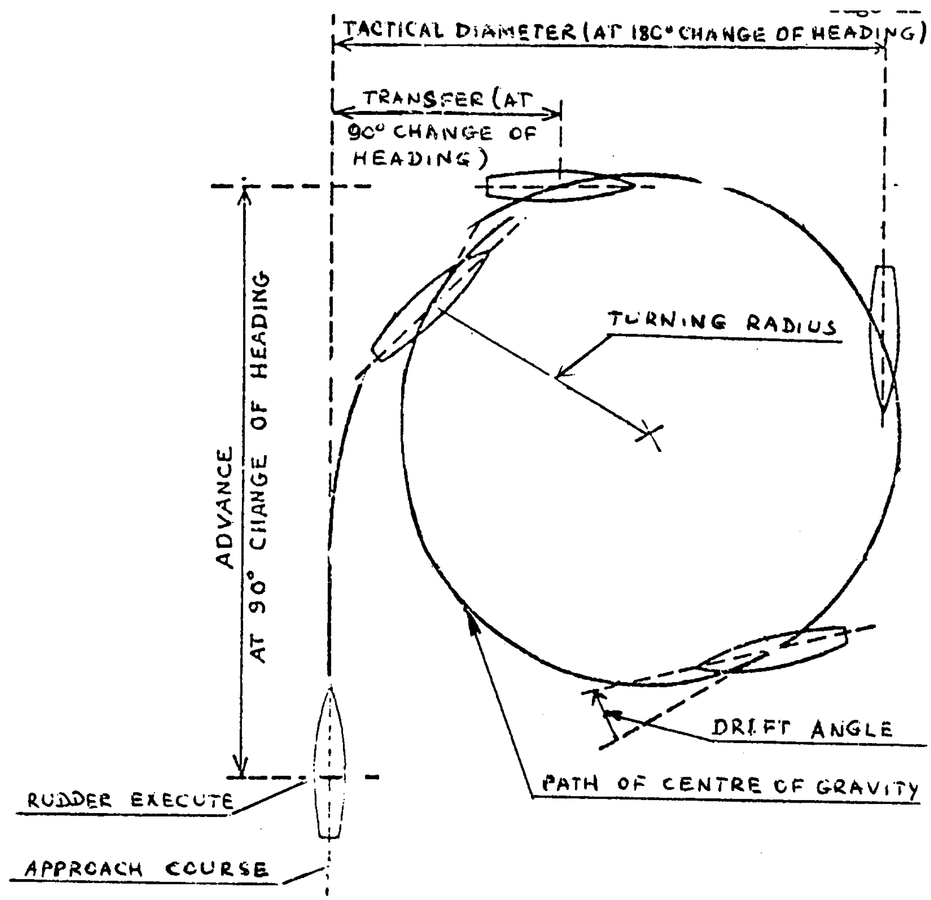

Fig.1 - Definitions used on turning circle tests

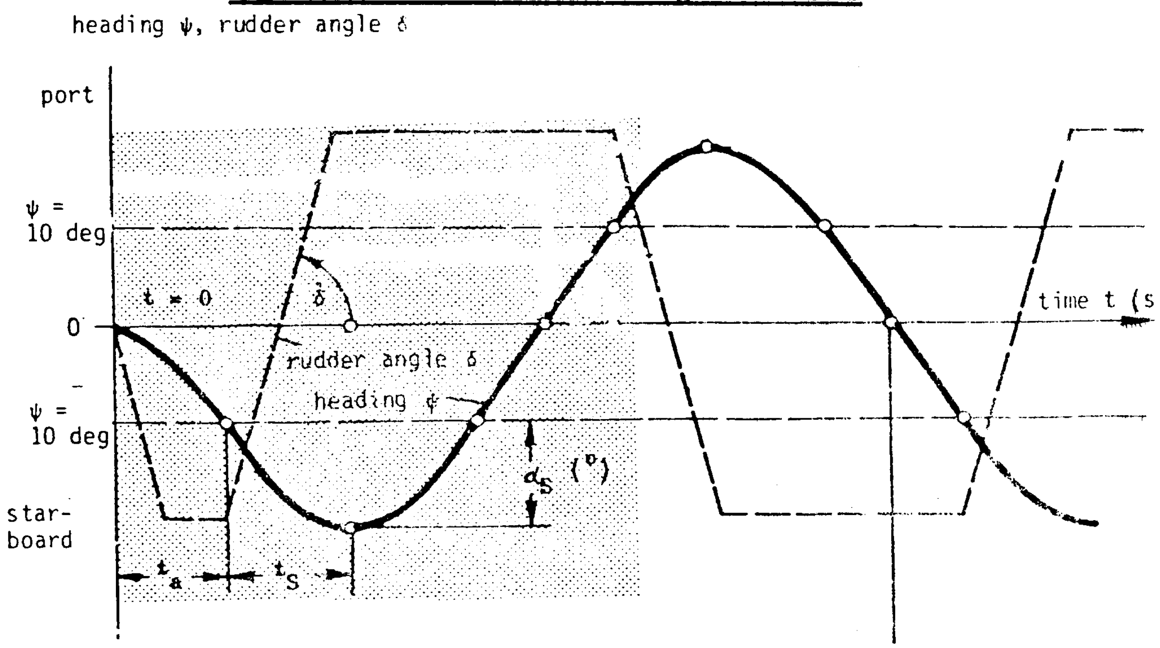

Fig.2 - Most important part of zig-zag test (example of $20^{o}/10^{o}$ zig-zag test)

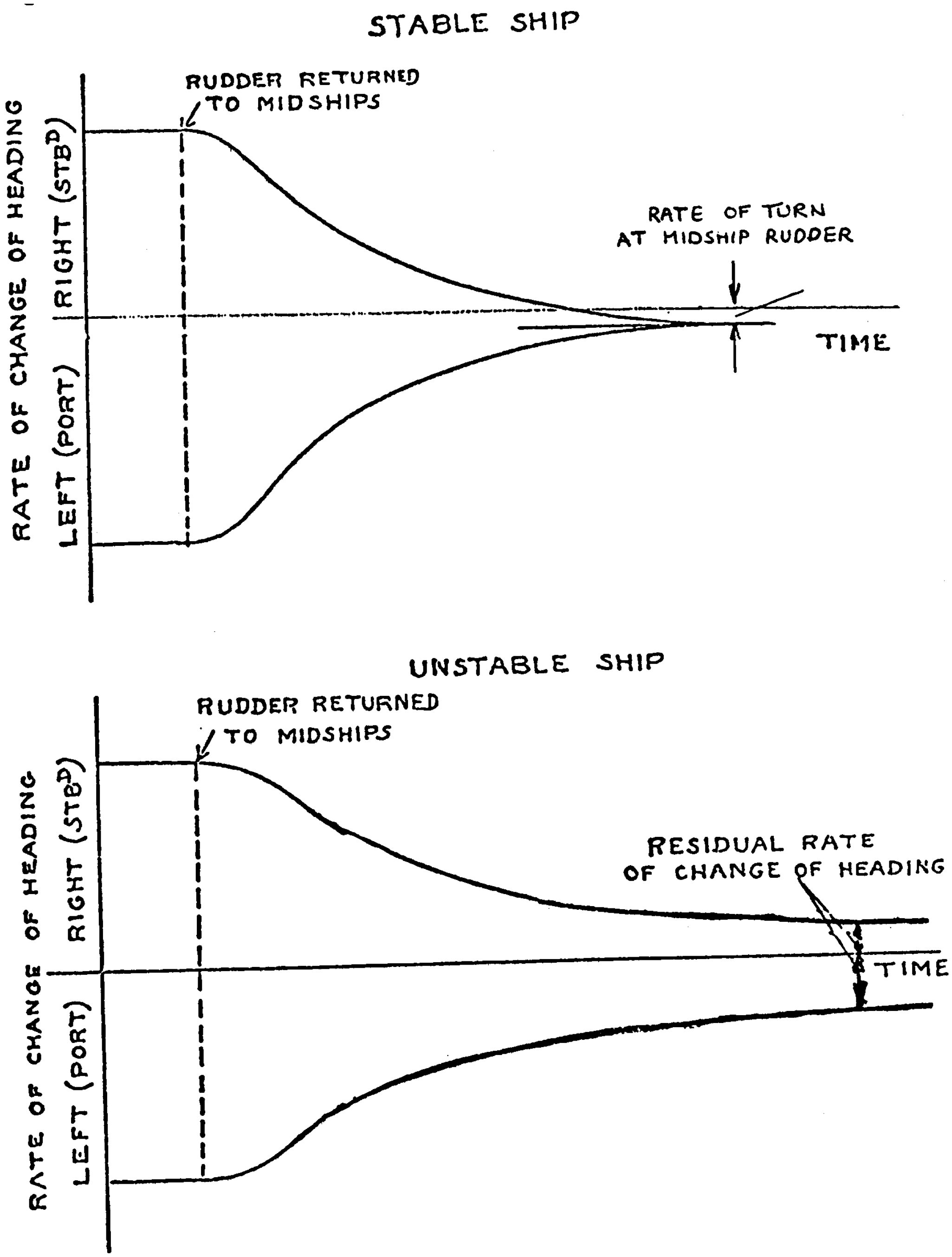

Fig.3 - Presentation of pull-out tests results

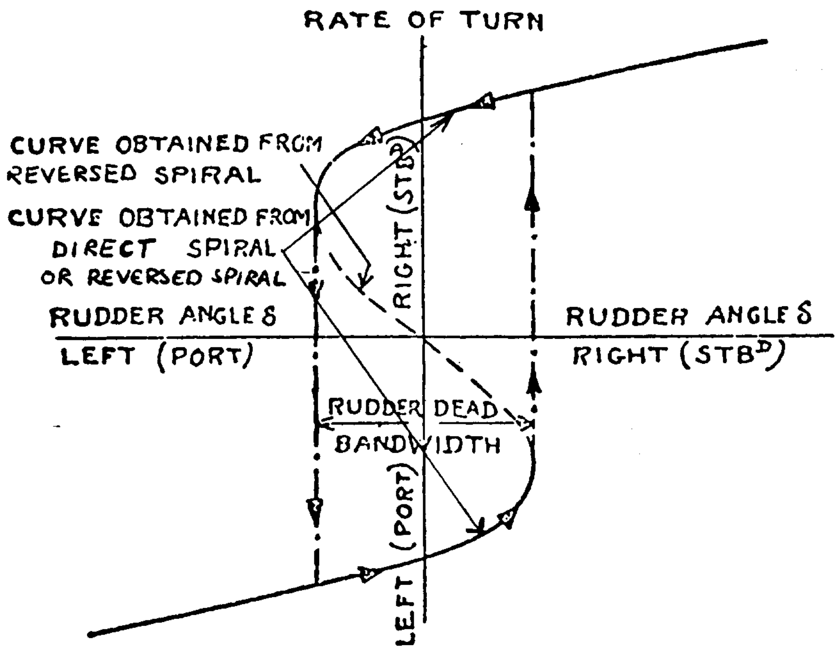

Fig. 4 - Presentation of spiral tests results for unstable ship

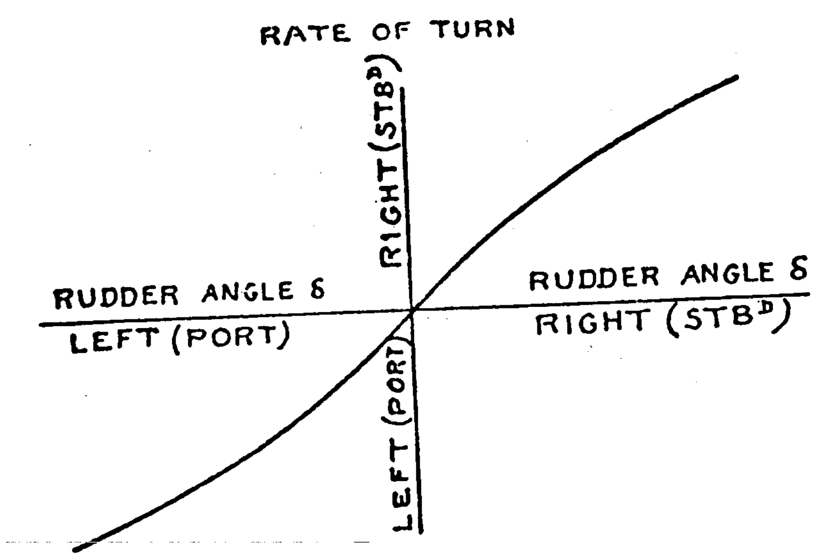

Fig. 5 - Presentation of spiral tests results for stable ship

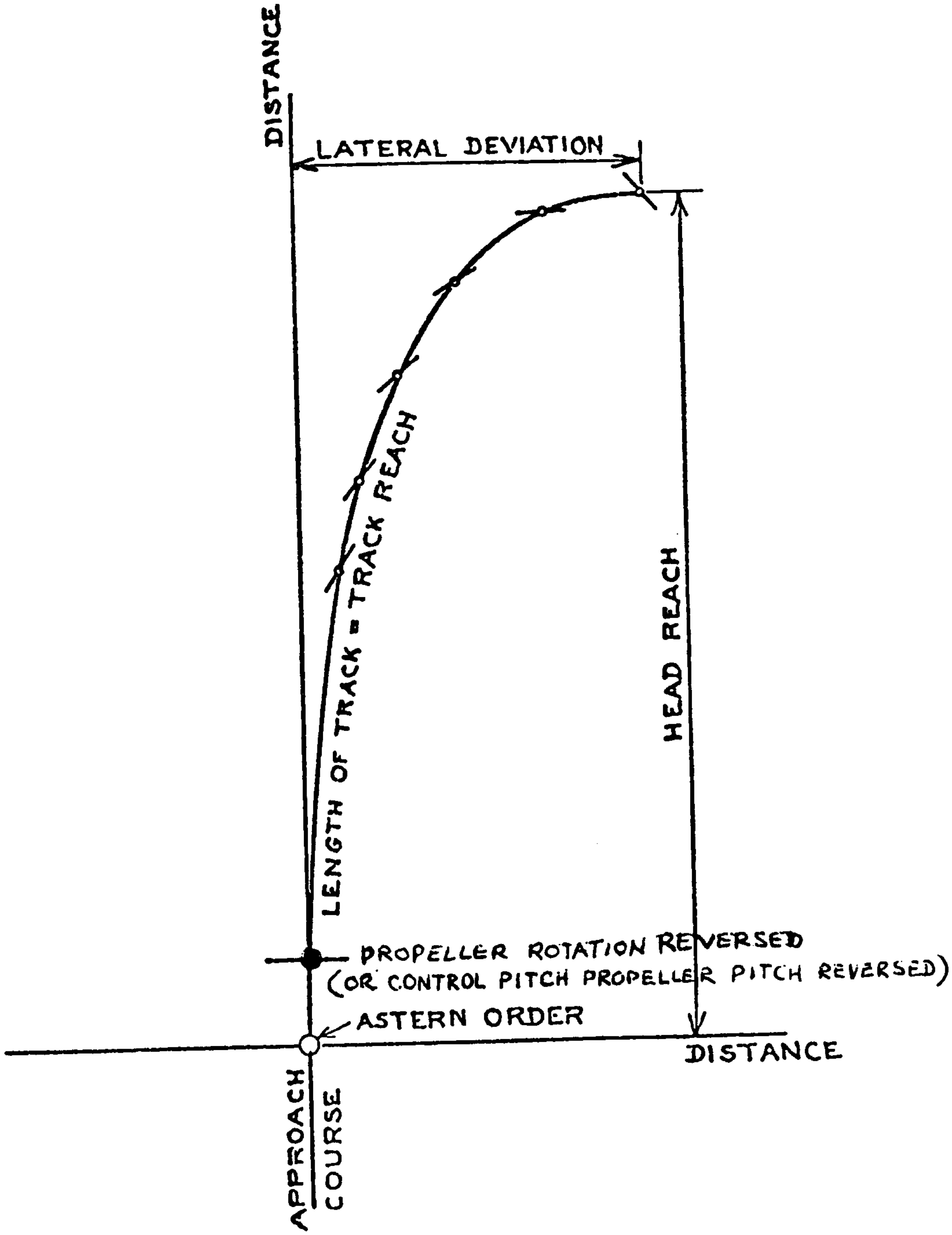

Fig.6 - Definitions used in stopping tests

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